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2π steering of surface plasmon polaritons with silicon nanoantennas

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Abstract. We experimentally demonstrate full-angle control over the direction of excitation of surface plasmon polaritons on thin gold film with a single silicon nanosphere. Upon oblique excitation of the nanosphere with circularly polarized light beam, the directivity pattern of the excited surface waves exhibits rapid wavelength-dependent steering, which is the result of combined action of chiral response of the nanoantenna driven by mutual interference of its magnetic and electric dipole moments and chirality of the incident wave.

1. Introduction

Robust spin momentum locking for surface and guided electromagnetic waves allows for their directional excitation with circularly polarized light or chiral antennas [1, 2]. This opens up great prospects in many areas from optomechanics to quantum nanophotonics [3, 4, 5]. Recently, it was shown that dielectric nanoantenna provides chiral response with strong spectral dependence due to the interference of electric and magnetic dipole momenta for specific excitation conditions [6]. Notably, the effect does not require elliptical polarization of the pump beam or the geometric chirality of the nanoantenna, and thus realizes the concept of directional coupling of surface waves *beyond* spin-momentum locking [7]. Since the chiral response due to interference of dipoles is induced normally to the plane of incidence, silicon nanoantenna provides resonant switching between forward and backward excitation of surface plasmon polariton modes within a narrow spectral band.

On the other hand, excitation of nanoantenna with circularly polarized light should provide switching of the excited SPP from left to right with respect to the plane of incidence depending on the helicity of light [8, 9]. Here, we show that by utilizing both these effects, full control over the direction of excitation surface wave can be achieved, and provide first experimental evidence of plasmonic beam steering for silicon nanosphere on metal substrate (Fig. 1a).

2. Experiment

Single silicon nanoparticles were fabricated using laser ablation of amorphous silicon films [10] and transferred to thin (40 nm) gold film using nanomanipulations under electron beam [11].

To demonstrate the effect of SPP directivity switching experimentally, we used the setup for leakage radiation microscopy combined with Fourier plane imaging optics [12]. SPP was launched



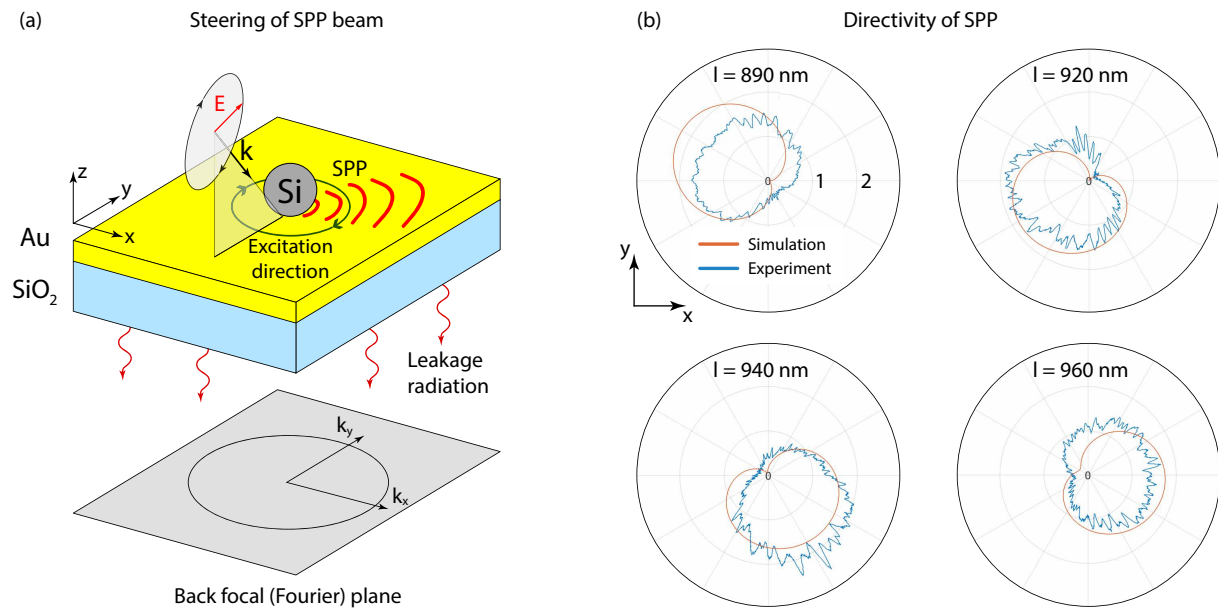


Figure 1. (a) Sketch of the experiment. SPP is excited silicon nanoantenna illuminated by obliquely incident circularly polarized wave. The directivity is measured using leakage radiation microscopy setup combined with Fourier plane imaging optics. (b) Measured and calculated directivity patterns of SPP at different wavelengths.

from the sphere by exciting it with a polarized laser beam with tunable wavelength incident at ≈ 25 degrees to the substrate normal and mildly focused with a 5 cm achromatic doublet lens. Spectral scanning was realized with Fianium SC400-6 supercontinuum source with acousto-optical tunable filter, which provided beam with central wavelength within 650-1100 nm range. The SPP leakage radiation present due to relatively small thickness of gold layer was collected from the bottom with an oil immersion objective (Zeiss 100x, NA=1.46). In the Fourier imaging optical channel, the incident beam was filtered with a beamstop to avoid camera overexposure.

We probe a 310 nm silicon nanosphere with circularly polarized excitation of different helicity and reveal the spectral evolution of the surface plasmon polariton (SPP) directivity patterns using leakage radiation microscopy setup combined with Fourier plane imaging optics [12]. The measured data show that within the spectral range where p-polarized light induces forward-to-backward switching of surface plasmon polariton from the nanoantenna [6], circularly polarized excitation enables wavelength-dependent steering of the directivity pattern. The measured SPP directivity patterns for several characteristic wavelengths are shown in Fig. 1b. The experimental data are in great agreement with the results of analytical calculation based on Green's function approach [13]. We show that by using both helicities of the incident wave, full 2π coverage of the direction of SPP excitation is possible.

3. Conclusions

In summary, we have experimentally demonstrated full-angle surface plasmon polariton beam steering with a single high-index dielectric nanoparticle. We showed that for particular angle of incidence, the combination of chiral response of dielectric antenna, which enables directional launching of surface waves within the plane of incidence, and helicity of the incident wave provides wavelength-dependent tuning of the surface wave excitation direction, thus realizing plasmonic beam steering. The experimental demonstration of the effect was carried out

via leakage radiation microscopy combined with Fourier plane imaging optics, which allowed to reconstruct full spectral dependence of the SPP directivity pattern for both helicities of the incident beam. Our findings have important practical implications for on-chip optical communications and surface photonics.

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